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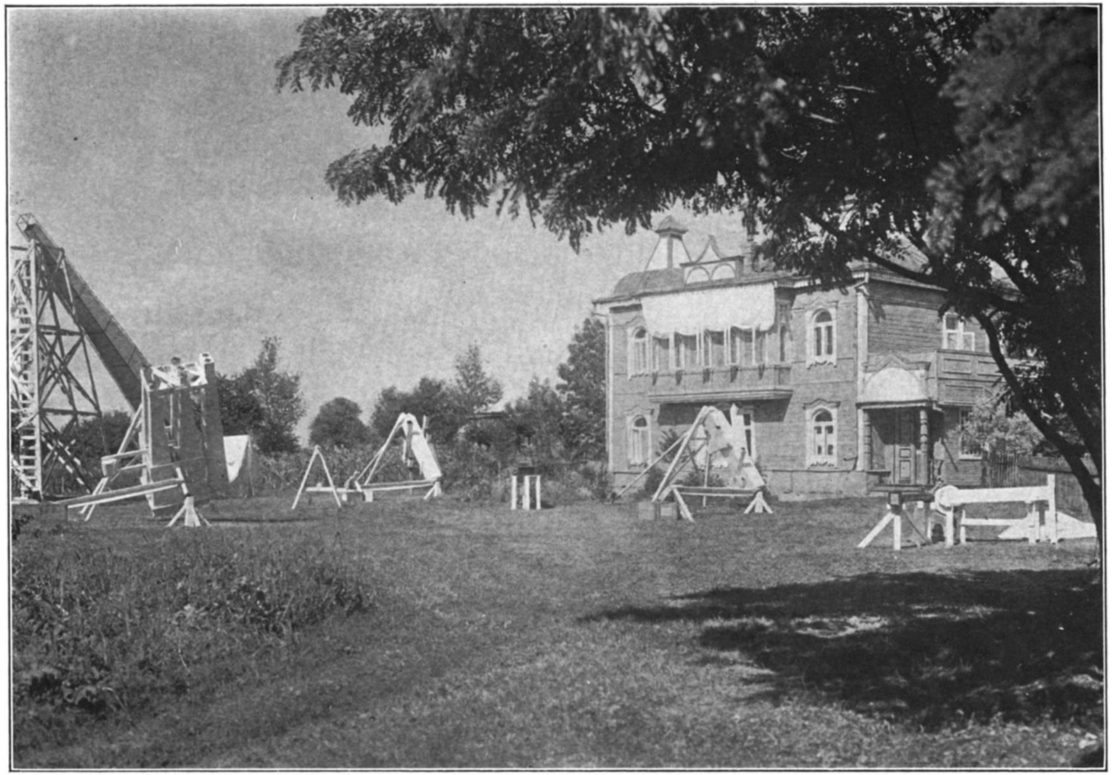

General View of Eclipse Camp at Datcha Lavrovskavo, Brovarý, Russia.

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THE LICK OBSERVATORY-CROCKER ECLIPSE EXPEDITION TO BROVARÝ, RUSSIA.

BY W. W. CAMPBELL AND HEBER D. CURTIS.

Tho this powerfully equipped eclipse expedition shared the ill-fortune of several other large eclipse parties in Russia in its failure to secure any results because of unfavorable weather conditions, a description of the camp, the equipment, and the proposed observations may not be without interest, and it should be a matter of record.

It is superfluous to express our gratitude to Regent WILLIAM H. CROCKER for the gift which made the expedition possible. Thru the gifts of Mr. CROCKER especially, his brother, and of Mrs. PHŒBE A. HEARST, the Lick Observatory has been enabled to send well-equipped expeditions to observe all the more important total solar eclipses since its completion in 1888, resulting in a collection of eclipse observations which is doubtless the most extensive in existence. For a number of eclipses in this interval of twenty-six years no attempt was made by the Lick Observatory to send expeditions because of known poor chances of success; and in nearly all these cases the lack of success by the astronomers who went has shown the wisdom of our abstention. That the present expedition cannot claim the success which seven out of our eight earlier expeditions experienced must be accepted as one of the "fortunes of war."

Accurate information bearing on the probable weather conditions at various possible sites along the path of totality was unusually difficult to secure. Published records seemed to leave no doubt that the probabilities of freedom from clouds were better the farther south one went, the cloudiness factor ranging from about 6.8 in Sweden and Riga to 2.3 in the Crimea, on a scale of 10 for total cloudiness. It was absolutely essential to be as near as possible to the central line for the observations to be made with the moving-plate spectrograph. The lowlands and other unfavorable conditions along the central line in the Crimea, and the advantages of nearness to a large city (other things being equal), finally led to the tentative selection of a site to be located as near as possible to the central line where this line passed thru the small town of Brovarý, some twelve miles northeast of Kiev, in the Government of Chernigov. Also, because of the fundamental requirement as to position on the central line, it was necessary to decline, with great regret, several very kind offers of sites. Mr. GREFS, Court Chamberlain to the Czar, with characteristically generous Russian hospitality, offered us a site on his country estate at Stavidly, a hundred miles, more or less, southeast of Kiev; the party of eight would be his personal guests, and he would supply all the labor and local transportation we needed. But the distance of Mr. GREFS's estate from the central line (13 kilometers) compelled us regretfully to decline this exceedingly generous invitation. That given after we reached Kiev by the Lord Mayor of Kiev to locate on his beautiful grounds, and Professor VOGEL's offer of a site in the large enclosure about the Kiev Observatory, were declined for the same reason.

In addition to the instruments, a full equipment of camp furnishings, supplies, and staple foods was taken, repeated experience having shown the great increase in comfort and efficiency to be gained by making a large eclipse camp an independent unit, with no need to rely upon local accommodations or sources of supply. The freight shipment, amounting to about four and a half tons, went by the steamer "Czar" of the Russian-American Line direct to Libau, Russia, which was reached on July 8th. It has been our invariable rule to have some member of the eclipse party accompany the freight shipment thruout its entire course; this has often saved serious delays and inconveniences. Mr. CURTIS accordingly accompanied the freight. It was planned for him to select a suitable site to the northeast of Kiev as close as possible to the central line, at which point Mr. CAMPBELL and the rest of the party would later join him, travelling via Italy and Austria.

The Russian Government had granted to foreign eclipse expeditions free entry for the instruments, provided none were left in Russia, free railway transportation of the instruments, and half-fare passenger tickets. The customs concession was interpreted rather strictly, so that more examination was deemed necessary by the officials at Libau than we had expected, but the officials showed the expedition every possible curtesy.

Mr. CURTIS reached Kiev on July 11th. The search for a suitable location proceeded rather slowly, as this was the summer vacation season, and nearly all officials or scientists who might be of service were away. However, invaluable assistance was rendered at this time and thruout our stay by several members of the Kiev Circle of Amateur Astronomers. To these gentlemen, in particular to Mr. NICOLAS ZENCHENKO, the able president of this society, and to Mr. IVAN ILIINSKY, a prominent member of the society, our heartiest thanks are due. During the days spent in the selection of the camp, thru the troubled and changed conditions brought on by the war, and until our final departure from Kiev, Mr. ZENCHENKO and Mr. ILIINSKY placed themselves unreservedly at our disposal, and were always ready to assist or advise. Our thanks are also due Mr. MEYER, for valuable assistance rendered at this time.

The site selected was the Datcha Lavrovskavo, a fine country estate belonging to Judge LAVROVSKOY, situated on the northern edge of the village of Brovarý, almost precisely on the central line, as corrected by the English astronomers on the basis of recent observations of the Moon's motion. The estate was unoccupied, as Judge LAVROVSKOY had been transferred to another district some time before, but by a very fortunate coincidence Madame LAVROVSKOY happened to be staying there for a few days, and arrangements for its rental were made at once. We are grateful for her curtesy in allowing us to occupy this fine site and for her assistance in arranging the first details of our occupancy. The Datcha comprised eleven acres, all enclosed, an excellent two-story residence, barns and outbuildings, cellar, conservatory, and even a small observation tower. A few hours' work converted the half-underground winter section of the conservatory into a very convenient dark room. There were many fruit trees, some larger timber, and a lawn in front of the house which offered an ideal site for the instruments.

Tents had been taken for the camp, and it had been planned to construct a kitchen tent, a large dining tent, and a dark room, but the fortunate location at the Datcha made all this unnecessary; a few tents were put up for the younger members of the party who preferred to sleep in true camp fashion, and for work tents. Brovarý is a typical Russian town of perhaps three thousand inhabitants, with unimproved dirt streets whose condition becomes indescribable after a heavy rain. A fine military road and a motor tram line connect it with Kiev. Kiev is a thoroly modern city of over half a million inhabitants, picturesquely located on high bluffs along the Dnieper River. The view of the gilded domes of its many churches and cathedrals, and the panorama of river and plain to be seen from the open-air restaurant of the Kupetchky Sobraniya (Merchants' Club) on a bluff overlooking the Dnieper, are very fine.

The freight was taken out to the camp on July 18th and unpacked; Mr. CAMPBELL and the other members of the party arrived on the 21st. The party numbered eight: Director CAMPBELL and Dr. CURTIS; Mrs. CAMPBELL and her mother, Mrs. ELIZABETH THOMPSON; and, in the capacity of voluntary assistants, Dr. CAMPBELL's three sons, WALLACE CAMPBELL (Harvard '16), DOUGLAS CAMPBELL (Harvard '17) and KENNETH CAMPBELL (Hotchkiss '17); and Mr. CHARLES F. BRUSH, JR., (Harvard '15). Within three days the living arrangements were perfected, and the real work of preparing for the eclipse was begun.

With the four energetic and active young Americans as helpers the work of setting up the instruments proceeded very rapidly; in fact, as time progressed, it became increasingly difficult to provide work for our insatiable young assistants. So rapidly did the work go that the last two weeks were easy, and everything could have been in readiness ten days before the eclipse. Mrs. CAMPBELL, as at several previous eclipses, was a most efficient "Secretary of the Interior," administering to our material wants with the assistance of a large domestic staff, and seeing to it that our drinking water was adequately boiled and sanitarily irreproachable. All in all, our life at the Datcha Lavrovskavo was a very pleasant one, and the members of the party will always remember it as a very delightful experience, except for the vital two minutes and fourteen seconds on the day of the eclipse.

The instruments were as follows:—

1. The 40-foot Telescope. This instrument, for large-scale photographs of the corona, was mounted as in previous eclipses, and no further description is necessary. With this instrument ten exposures varying from instantaneous to 32 seconds were to be made on 14 × 17-inch plates. It was in charge of Mr. WALLACE CAMPBELL, assisted by Mr. GEORGE M. DAY. Mr. DAY and his family are the only Americans in Kiev, to the best of his knowledge; he is in charge of the International Y. M. C. A. work in Russia, and we take this opportunity to thank him for the many important ways in which he assisted us.

2. The Polarizing Photometers. These instruments were the same as those used in the eclipses of 1905 and 1908, with the exception that light tubes and diaphrams were provided in front of the objective ends so as to prevent the entrance of light from any other region than that immediately about the Sun. Two of these photometers reflected the light from the corona into the cameras by means of unsilvered glass flats placed at the polarizing angle, and the photometers were mounted at 90° to each other. A third camera was pointed directly to the corona, the aperture of the lens being stopped down to 0.62 inches. The apertures of the others are two inches each, and the focal lengths of all three are very close to fifty inches. These polarigraphs, and the one-prism spectrograph described in the next paragraph, were mounted on the northern polar axis. This axis and its instruments were in charge of Mr. DOUGLAS CAMPBELL, assisted by Mrs. CAMPBELL, Mr. ZENCHENKO, and Mr. MERELLI.

3. The One-Prism Spectrograph. Image lens 1.62 inches aperture and 12.75 inches focal length; collimator lens two inches aperture and 32 inches focus; camera lens 2.06 inches aperture

and 12.40 inches focus; and a 60° prism set for minimum deviation at Hγ. Purpose, the photography of the coronal spectrum, and a study of the light distribution in the coronal spectrum.

4. Three-Prism Spectrograph for accurate determination of wave-length of the green coronal line. Three very dense flint 60° prisms; image lens 2.12 inches aperture and 20.2 inches focus; collimator lens 2.5 inches aperture and 20.96 inches focus; camera lens 2.06 inches aperture and 17.92 inches focus; curved slit with radius of 3.3 inches; total deviation 169° 39′.

5. Objective Grating Spectrograph for study of distribution of the gas in the inner corona which forms the green ring in the spectrum of the corona. Michelson plane grating 15,000 lines to the inch, ruled surface 2.68 by 3.86 inches, used in the second order: a triple camera lens 3.25 inches aperture and 24 inches focus, corrected for the D region of spectrum.

6. Ultra Violet Objective Spectrograph. Single U. V. glass prism, 60°; triple U. V. glass lens 2.60 inches aperture and 78.74 inches focus; corrected for wave length 3500. Purpose, to record violet and ultra violet coronal spectrum, and the photometry of the spectrum. The three spectrographs last mentioned were mounted on the southern polar axis, and were in charge of Mr. CHARLES F. BRUSH, JR.

7. Moving Plate Spectrograph for "flash" spectrum. Two 60° prisms giving a deviation at Hγ of 100° 8′; triple camera lens, corrected for Hγ, 2.12 inches aperture and 60 inches focus. The plate-holder movement was controlled by a valve regulator on a glycerine clepsydra cylinder, as used in the eclipses of 1905 and 1908. The exposure at this instrument was by Mr. CAMPBELL; it was mounted nearly horizontally in such a position that the tangents to the cusps at second and third contacts would be parallel to the refracting edge of the prisms, and it received its light from a coelostat.

8. The Floyd Telescope, five inches aperture and 70 inches focal length, for smaller-scale photographs of the corona, was mounted horizontally, receiving its light from the same coelostat as the moving-plate spectrograph. The exposures at this instrument were in charge of Mr. LINNIK.

9. Four Cameras with lenses of three inches aperture and 11 feet 4 inches focal length. These lenses, and the sheet steel tubes in which they were mounted, had been used in previous eclipses in the search for intramercurial planets. While it was the intention to search for such objects on the plates taken with these instruments, this was secondary to the main purpose. It is an interesting consequence of the theory of relativity that a beam of light passing thru a gravitational field should suffer a minute deflection; the total amount of this deflection for a ray from a star passing close to the limb of the Sun would be 0″.93 of arc. The doubled effect, for a pair of stars situated on opposite sides of the Sun and 20′ distant from the limb, would amount to three-quarters of a second of arc.[1] At present this seems to be about the only physical observation which we can make to test the theory of relativity, and naturally it can be made only at the time of total solar eclipse. Professor EINSTEIN, the chief developer of the theory of relativity, has been quite anxious that eclipse observations be made to decide the question of the existence or non-existence of such a deflection of light when passing thru a strong gravitational field. While a deflection of the rays from nearby stars, if found, might be complicated with questions as to the amount of refraction caused by the rare matter of the corona, the problem seemed to be of sufficient importance to warrant a thoro trial. The tubes were so arranged that the Sun's image fell in the center of each of the four 16 × 20-inch plates used. The axis on which these tubes were mounted was rated for sidereal instead of solar time. Comparison plates of the eclipse region of sky were taken at Mount Hamilton with the instrument set up exactly as it was to be used at the eclipse, and with exposures of the same length as that to be obtained at the eclipse. By measuring the stars found near the Sun on the eclipse plates, and comparing their positions with the positions given for the same stars on the comparison plates, any changes due to the action of the Sun in bending the rays of light passing near it, could, it is believed, be detected.

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[1] Cf. articles in the *Publications of the Astronomical Society of the Pacific*, **23**, 219, 272, and **25**, 77.

As *Regulus* was very favorably placed, slightly over a degree from the eclipsed Sun, a fifth lens of the same size and focal length was mounted with the other four, having an ocular provided with cross-wires, and set by calculation so as to have *Regulus* central when the Sun's image was central on the large plate; it was hoped to be able to use *Regulus* in this way as a guiding star, to insure perfect roundness in the star images. This mounting was in charge of Mr. CURTIS, who was assisted by Mr. MORGILEVSKY and Mr. ILIINSKY.

10. Extra-focal Photometers. These were mounted on the same axis as the four lenses for the relativity test, and consisted of two other lenses of the "Vulcan" type mounted seven inches apart in the end of a double camera tube. The images of the Sun formed by both these lenses fell upon the same 14 × 17-inch plate at the lower end. The lenses (of three inches aperture and eleven feet four inches focal length), were mounted three inches out of focus, and one of the pair was stopped down so as to give a light reduction of one magnitude. By means of standard squares on the plate and the extra-focal images of the corona and of *Regulus* it was hoped to secure photometric results of considerable value, and data as to the density of the matter forming the corona.

11. A Chronograph was mounted and connected with the observing chamber of the 40-foot telescope for recording the times of second and third contacts; it was also connected with automatic contacts on the exposing shutter of the moving-plate spectrograph to record the exposure times with that instrument.

The signals at predetermined intervals before totality, and the counting of the seconds for the observers were given by KENNETH CAMPBELL. General NICOLSKOY and his son, with a small telescope for visual observations of the corona and prominences, were also at the camp on eclipse day.

All the plates of the various photometric programs, and selected plates of the 40-foot and Floyd programs, were standardized by the imprinting of photographic squares from an amyl-acetate lamp, the principle of equal exposures in equal times at varying distances being followed as far as possible, instead of varying exposures at a fixed distance.

Mr. WALLACE CAMPBELL had charge of the meteorological observations at the camp. The geographical co-ordinates of the camp at Datcha Lavrovskavo are as follows, determined by sextant observations for latitude and time and by transport of our chronometer to the Observatory of Kiev for longitude:—

Longitude, $2^h\ 3^m\ 5^s.5$ E. of Greenwich
Latitude, $+50^\circ\ 30'\ 24''$

We are indebted to Professor VOGEL, Director of the Royal Observatory, Kiev, for the comparison of our chronometer time with accurate Kiev time.

We had not been very long in camp before it became evident that the chances for success on August 21st were very, very slight. To quote from Mr. WALLACE CAMPBELL'S report on the weather conditions during our stay:—

"Of the thirty-five days during which the party was at the station, only ten could be called at all favorable for eclipse observations at 2.47 P. M. (the time of mid-totality), and the conditions on these days were not satisfactory. Not one day of the thirty-five was entirely clear at eclipse time. On average days if a storm was not in the neighborhood the conditions were these: cumulus clouds appeared in a clear sky about 10 A. M., and increased steadily to a maximum of about eight-tenths between 2 and 3 P. M. The cumulus then decreased, disappearing by sunset, and the nights were clear."

Observers at Minsk, Theodosia, and other places on the line of totality report precisely the same state of affairs, and examination of weather records for the past ten years shows that this is the rule in the summer weather of western Russia. That this fact, so salient and so vital from an eclipse standpoint, namely, that the maximum of day cloudiness came almost precisely at eclipse time, was not noted and communicated to intending observers, seems to have been an inexplicable omission. It is not too much to say that the Lick Expedition would not have been sent had this important fact been known in advance.

Stormy conditions prevailed on the 19th and 20th, and the "tail" of this storm, which so fortunately left clear weather in Sweden and Riga, was just passing at eclipse time on the 21st.

Nothing could be seen of the eclipsed Sun, and no observations of any sort could be made. Ten minutes later a little might have been secured thru a cloud gap, and one hour later the region about the Sun was beautifully clear. The temperature fell irregularly for fifteen minutes after the first contact, then uniformly until twelve minutes after the end of totality. The total fall was 2°.6 C. The rate of fall was not noticeably increased during totality. The eclipse was a very dark one for us, probably owing to the thick clouds. Messrs. JONES and DAVIDSON, at Minsk, secured excellent results thru a clear space in the generally clouded sky; in the Crimea, Dr. PERRINE and Professor NEWALL were unfortunate enuf to strike a cloud between two clear spaces, and secured no results. Several small parties in the Crimea, however, located but a short distance away, had spaces of clear sky about the sun at eclipse time and were successful.

Some ten days after starting life in camp came the order for the Russian mobilization, and we shall always remember the long sad procession of rude carts which passed the Datcha early one morning, transporting the men of our little town to their mobilization depot. The priests, carrying the glittering icons and banners, gave them their blessing, and the scenes of parting with the wives and children were heart-rending; it was already a tragedy to these peasant women, left behind to gather in their little crops for the winter, and we could but recall that this same tragedy was doubtless at that time being multiplied ten thousand fold by similar scenes in nearly every square mile of Europe. Then came in quick succession those declarations of war which have embroiled Europe in a catastrophe such that the wildest writer of fiction could not have predicted or imagined six months ago. Tho Kiev is one of the main mobilization centers, the existence of a state of war did not materially change life in the city, and in our quiet Datcha we experienced only a few minor annoyances, but no serious difficulties. We were impressed with the thoro and business-like character of such portions as we saw of the Russian mobilization; when we left, one month after the declaration of war by Germany, there were still forty great troop trains a day passing thru Brovarý, and earlier in the mobilization there were more. Communication between Brovarý and Kiev became more difficult and uncertain. All gasoline was commandeered, and the never-too-reliable tram was forced to use kerosene instead, while the great Alexander Chain Bridge over the Dnieper was frequently closed for hours at a time for the passage of troops or interminable batteries of heavy artillery. We had intended to bring our Russian volunteer assistants from Kiev to the camp by automobile for the preliminary drills, but all automobiles were taken for military purposes, and according to military proclamation no civilian could even ride in an auto on the streets of Kiev without a permit from the commandant. "International complications" arose over our jewel of a cook; born in Berlin, she had been so long in Russia that her German speech was not above reproach; able to read and write neither Russian nor German, she did not seem at all dangerous, but no exception could be made to the general order which placed under supervision or detention all German or Austrian subjects. The arrest of this energetic character left such a gap in the internal economy of the camp, that all our influence and that of our Russian friends was at once exerted, with the result that after four days she was brought back rejoicing to a welcoming camp. We were treated with great consideration by the officials, and we realized that the small annoyances and troubles we occasionally experienced were due solely to war conditions, and would never have been met with under ordinary circumstances. The German expeditions at Theodosia were not permitted to set up their instruments; the older members of the parties were ordered to leave at once; Doctors FREUNDLICH and ZURHELLEN of the Berlin Observatory and their mechanician MÉCHAU, being reservists in the German army, were detained, and are believed to be at present in the Volga district as prisoners of war.

There seemed to be no cause for anxiety as to any hostile action on the part of the simple, kindly Russian peasants, but, that there might be no reason why these should in ignorance be inclined to connect three such events as the eclipse, the American party and the war, brief and sensible proclamations were published by the Governors of Kiev and Chernigov, and by the Metropolitan of the Greek Church in Kiev, explaining the phenomenon. The *ispravnik,* a high official of our district, thought he would do the same, and his proclamation is one of our cherished mementoes of the trip; he advised that the children should be kept indoors and the cattle not be sent out to the fields on the day of the eclipse!

As no civilian freight was being carried by the railroads, the disposal of our instruments became a problem, but this was solved thru the kind assistance of General NICOLSKOY, who secured special railway transportation from Kiev to the Russian National Observatory at Poulkowa, where Director BACKLUND is kindly storing the instruments. Whether they are still in storage there, or are being sent to us via Vladivostock and the Pacific, we do not know.

For two weeks before we left the observing station we gave considerable thot to the problem which was always referred to as "getting out." The party had railway tickets, purchased before leaving America, reading thru Berlin and Paris, to London, but manifestly no longer of value. The route via Odessa and Constantinople was impossible, as the Russians daily anticipated that Turkey would declare war. A direct rail journey from Kiev to Petrograd, under the war conditions, was very uncertain, and the route via Moscow, Petrograd, and Finland was the only practicable one save that via Siberia. It was feared that the trip would be a long, and perhaps a very trying one. Only one passenger train a day ran from Kiev to Moscow, and neither money nor influence could guarantee a seat on this long, slow and crowded train. As it turned out, this portion of the journey homeward was the only really unpleasant part; from Moscow on, while there was always uncertainty, good accommodations were available. From Moscow we went to Petrograd. Two days were spent there, as the movement of troops in Finland and the taking off of certain trains made it impossible to leave more quickly. It seemed advisable to get to London at the earliest possible moment, partly because of rumors that nearly all Atlantic passenger steamers had been taken off for troop-transport service, but principally because on each section of the journey (except in Sweden and Norway) it was impossible to get reliable information concerning available travel facilities on the next section. It was important to "keep coming." Aside from cloudy sky on August 21st, our great disappointments were that we could not take time to visit the Poulkowa Observatory, nor to see our good friends in Stockholm. Professor and Mrs. BACKLUND and Professor BELOPOLSKY kindly came to Petrograd to see us and assist us. We take pleasure in acknowledging a great many acts of kindness and assistance to the expedition by Professor BACKLUND, and also the favors extended us by the Russian Imperial Academy of Sciences.

At Petrograd we were joined for the trip "out" by Messrs. PERRINE and MULVEY of Córdoba, who had been at Theodosia, and Messrs. JONES and DAVIDSON of Greenwich, who had been at Minsk. Passing through Finland, we stopped half a day at Tammerfors, a wonderfully clean Finnish manufacturing center; from here we went to Raumo, Finland, where steamer was taken for Stockholm. Twice on this trip passengers were ordered below decks while the steamer threaded passages on the Swedish coast. The youngest member of the party, with American longing for excitement, frequently expressed the hope that we might see a German cruiser, a wish which was not at all echoed by our English colleagues.

After a pleasant day at Christiania, the party went on to Bergen, thence by steamer to Newcastle, England. The lifeboats were in unostentatious readiness on this trip, but no mine was met with, and the party were very glad to step upon English soil, where everything seemed outwardly to be perfectly normal and going on as usual. Mr. BRUSH, by a quick trip across England, just managed to catch the steamer on which he had engaged passage. DOUGLAS and KENNETH CAMPBELL, unable to reach Rotterdam for their steamer, had a novel experience of traveling home by steerage. The rest of the party, unable to secure any earlier steamer accommodations than those they had engaged in March, spent two very enjoyable weeks in London, and reached Boston on the 30th of September, glad to be once again in a land where, to quote one of our number, "we are citizens and not subjects."